Preliminary kinetic validation of a thoracolumbar musculoskeletal model using sensitivity analysis

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Preliminary kinetic validation of a thoracolumbar musculoskeletal model using sensitivity analysis

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INTRODUCTION

Adolescent **I**diopathic **S**coliosis (AIS) is identified as a multifactorial disease and the aetiopathogenesis behind AIS has remained controversial [1]. There is a strong suggestion that a more reclined and back flat spine can cause instability in the spine and shear forces play a role in the onset of AIS [2]. In this study, using a recently developed thoracolumbar musculoskeletal model, we performed a sensitivity analysis on intradiscal shear forces as a part of kinetic validation of the model and also to investigate the effect of reclined back on intradiscal shear forces.

METHODS

Bi-planar radiographs of a 13-year-old patient with a right mild thoracic curve of 8° Cobb angle and a left thoracolumbar curve with a 10° Cobb angle were used to determinate the model posture in the preliminary stage of scoliosis.
Two parameters were used in this study. The first parameter represents the sagittal spine posture (SSP), which addresses all the sagittal plane parameters that we need to drive the model. Note that the patient's spine was a bit backwardly reclined compare to the normal spines. The second parameter describes the scoliosis progression (SP), which contains all the parameters of the model.
Two stages were created and compared to each other. Both stages were started from a straight spine, which is the first step in the model. The first stage was referred to as a normal spine which had 5% linear progression of whole scoliosis (SP = 5%). The second model corresponded to the radiographs, which is 100% of the progression (SP = 100%).
In this study, we assessed the backwardly reclined spine effect on the thoracolumbar intradiscal shear forces using a sensitivity analysis. We calculated the sensitivity matrix using finite differences. Then, we validated it by comparing the results of the linear approximation with results obtained running a full simulation of the model for changes of 1% in the parameters. The maximum error of the intradiscal shear forces obtained was less than 1% in the whole spine. Thus, we consider the sensitivity matrix accurate for this amount of variation of parameters.

RESULTS AND DISCUSSION

We can infer by the sensitivity analysis that in both stages, sagittal orientation has the most effect on the total force and anterior-posterior (A-P) shears due to the negligible difference caused by SP and solely SSP variation. In another word, the frontal parameters have a minor impact on the total forces and A-P shears in the thoracolumbar region. These results were expected and can be used as a sanity check of the kinetic model. However, by comparing the first and second stages, A-P shears are more sensitive to the reclined spine compared to the normal spine. Thus, we have to be more careful with more backwardly reclined spines while doing intervention because these shear forces could cause more progression. Figure 1 shows the derivative of the antero-posterior shear force in the first and second stages with SSP and SP variations.
Another comparison in both stages and parameters deduced that coronal and axial parameters (i.e. Cobb angles) have the main impact on the lateral shear forces. The derivatives of these shears are extremely high in the first stage that is almost a normal spine but reduces in the next stages when scoliosis progresses, as expected. Further, the normal spine has more lateral shear derivation compared to a scoliotic one while SSP alters. However, these forces are too small in the normal spine and we expect to have greater variations in the normal spine.
All these results indicate that the kinetics of the model correspond to the expectations, which is a sanity check for the kinetic validation of the model.

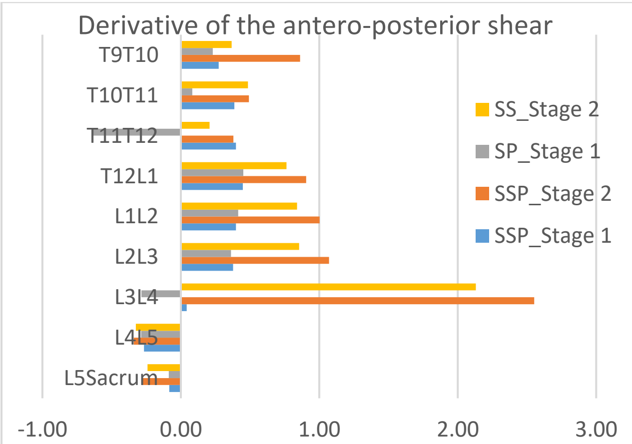

Fig. 1 Derivative of the antero-posterior shear force in the first and second stages with SSP and SP variations

CONCLUSIONS

We performed a sensitivity analysis on intradiscal shear forces in a scoliosis patient with a backwardly reclined spine as a part of the kinetic validation of the model. The results corresponded to the expectation, which can be a sanity check for the model. Further, we can simulate and test some of the existing hypotheses with the model and improve the intervention processes.

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REFERENCES

[1] C. Wong, *Scoliosis*, **10**-1, 1–5, 2015
[2] R. M. Castelein, et al., *M.H.*, 65-3, 501–508, 2005.